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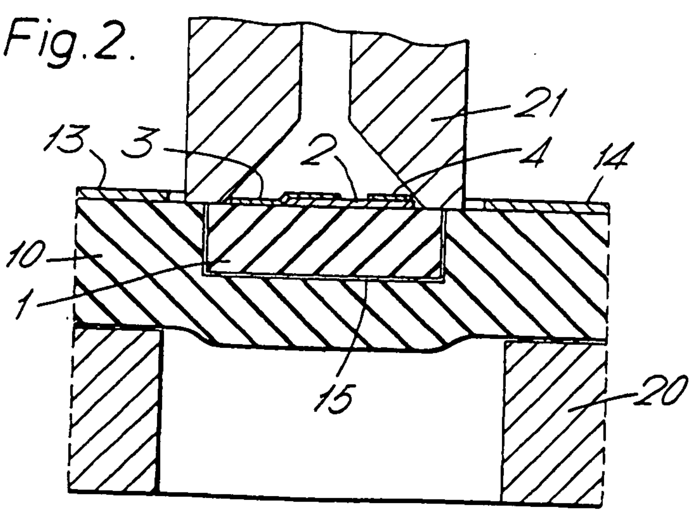
(58) Field of search
H1K

(54) Methods of manufacturing a microwave circuit

(57) In the manufacture of a microwave circuit a semiconductor device body (1,2) is pressed into the surface of a circuit substrate (10) to deform the substrate (10) locally so as to form a recess (15) having substantially the same shape and depth as the device body (1,2). The device body (1,2) is held in the substrate (10) by the abutting walls of the recess (15), and low inductance connections are formed by conductive layer portions (23,24) extending directly across the adjacent edges of the device body (1,2) and of the recess (15). In this manner prior art problems associated with diode bodies in larger recesses are avoided. Deformation of the lower face of the substrate may be reduced, or insertion of the semiconductor body into substrates of less readily deformable material may be facilitated, by provision of an initial recess of smaller dimensions than the semiconductor body (Figure 4).

Fig.2.



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The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

Fig.1.

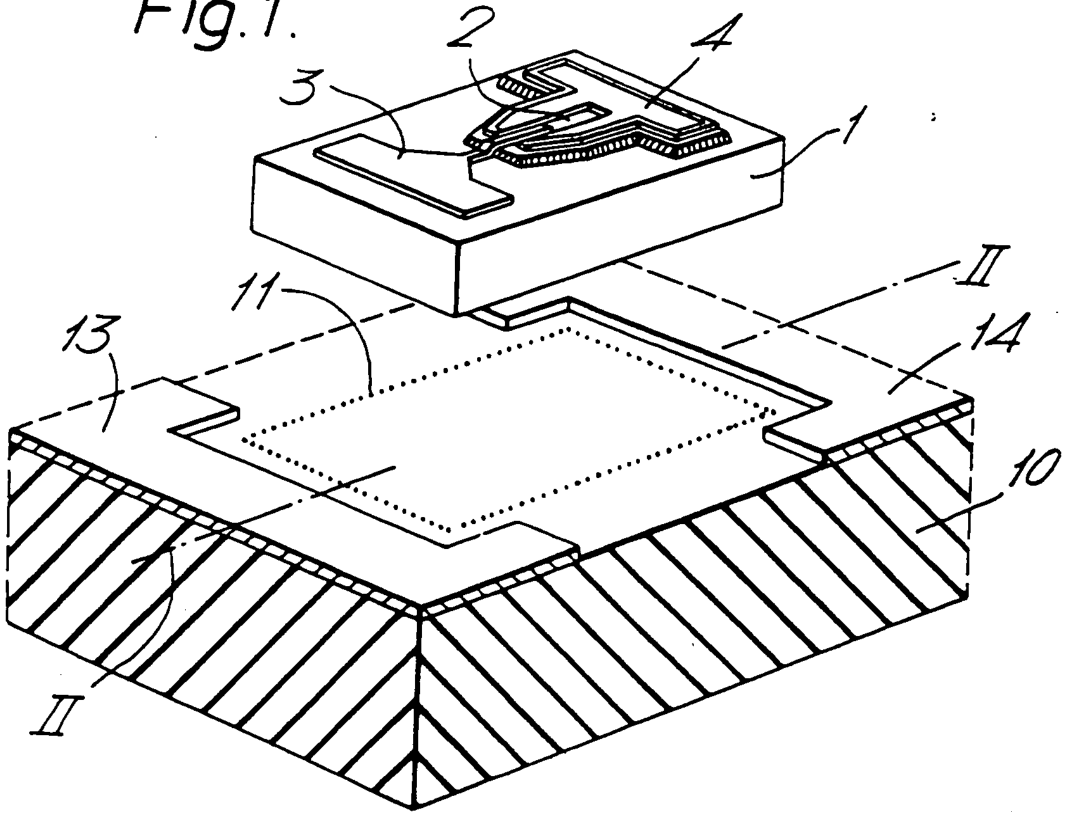


Fig.2.

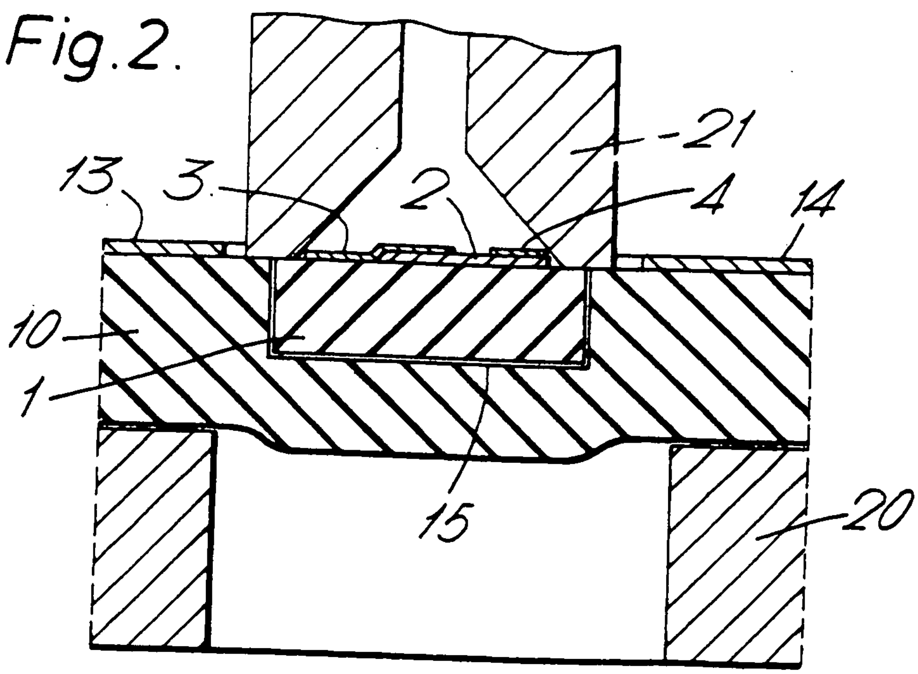


Fig.3.

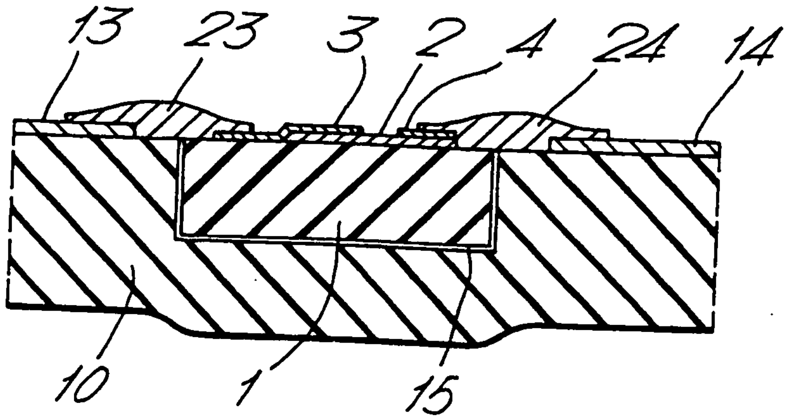
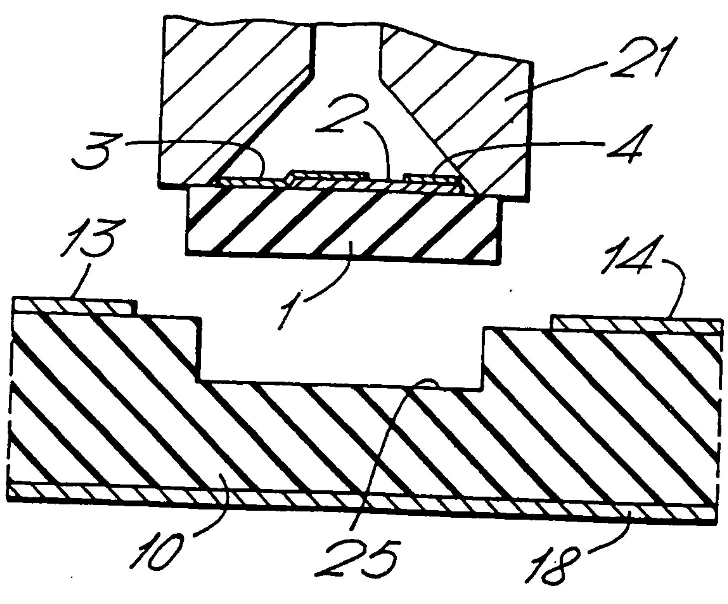


Fig.4.



SPECIFICATION

Method of manufacturing a microwave circuit

This invention relates to methods of manufacturing a microwave circuit, particularly but not exclusively for operation at millimetre wavelengths, in which a semiconductor device body is mounted in a recess on a dielectric substrate of the circuit and electrically connected to a conductor pattern at the upper surface of the substrate.

In the paper entitled "Millimetre Wave Low Noise E-Plane Balanced Mixers Incorporating Planar MBE GaAs Mixer Diodes" by R.N. Bates et al published in the I.E.E.E. 1982 Microwave Theory and Techniques Symposium (MTT-S) Digest, pages 13 to 15, particular microwave Mott mixer diodes of GaAs are described having substantially coplanar electrode terminal areas. These diodes are mounted on a microwave circuit substrate which is thin, has a low dielectric constant and comprises conductor patterns of the so-called "finline", "microstrip", and "coplanar line" types. The finline circuits were produced with dielectric substrates of a glass microfibre composition available under the trade name "RT/duroid", and the diode bodies were mounted using electrically conductive epoxy with the diode bodies either inverted in a so-called "flip-chip" arrangement or accommodated in recesses in the substrate surface. The recesses were cut into the substrate using a tool having a punch-head which is slightly larger than the diode body after which the diode body is provided in the recess and electrically connected to the substrate conductor pattern by the conductive epoxy.

In this known technique, the punch-head needs to be slightly larger than the diode body to ensure that the diode body can be properly accommodated in the recess having regard to the manufacturing tolerances in the size and shape of the bodies. However this results in most diode bodies being a loose fit in the recess so that the conductive epoxy may run down the adjacent side walls of the body and recess. The resulting irregular shape and varying length of the epoxy connections increases the inductance of the connections in a non-reproduceable manner and in particularly undesirable for microwave circuits operating at millimetre wavelengths. When the epoxy is applied to the loose diode body it may even pull on the body and cause the body to tilt onto its side in the recess. Even when successful connections are made to the diode body the loose diode body may not be sufficiently held in the recess by the conductive epoxy connections in some cases so that the D.C. or microwave performance of the diode may become degraded when subjected to acceleration tests.

According to the present invention there is provided a method of manufacturing a microwave circuit in which a semiconductor device body is mounted in a recess on a dielectric substrate of the circuit and electrically connected to a conductor pattern at the upper surface of the substrate, characterised in that the recess is formed with substantially the same shape and depth as the device body by pressing the device body into the surface of the substrate to deform the substrate locally until the upper surface of the device body is at substantially the same level as the conductor pattern beside the recess, and in that the electrical connections are formed by conductive layer portions which extend directly across the adjacent edges of the device body and of the recess. Surprisingly it has been found that the semiconductor device body can be pressed into a microwave circuit substrate to form the recess and without damaging the device body because the substrate can be formed of dielectric materials such as glass microfibre compositions which are relatively easily deformable. Because the shape and size of the recess is determined by that of the device body, the device body can be held in the substrate by the walls of the recess so avoiding the problems with loose device bodies. Furthermore the walls of the recess abut those of the device body so that the conductive layer portions extend directly across adjacent edges of the device body and of the recess and can be of a short reliably reproduceable length between electrode terminal areas of the device body and the substrate conductor pattern. This permits these connections to have a very low inductance which is particularly advantageous for circuits operating at millimetre wavelengths.

The pressure with which the device body needs to be pressed into the substrate depends on the nature of the substrate material. In order to keep the pressure below that acceptable for the device body, it can be beneficial to use substrate materials which can be locally deformed by thermocompression. Thus, the device body may be heated so as to deform the substrate locally by thermocompression. Particularly with thick substrates it can also be useful to heat the substrate as well as the device body. In some cases the substrate may be heated instead of the device body.

The substrate may be sufficiently thin and deformable that pressing the body into a flat upper surface of the substrate causes the lower surface to deform slightly outwards directly below the recess. In the case of thicker or less deformable substrates or in situations in which it is desired to avoid or reduce deformation of the lower surface, it is advantageous to adopt a method in accordance with the invention in which, before pressing the device body into the surface of the substrate, a smaller recess is formed at the area of the upper surface where the device body is to be mounted, and this smaller recess is enlarged to have substantially the same shape and depth as the device body by pressing the device body into this smaller recess.

Embodiments of the invention to illustrate these and other features in accordance with the present invention will now be described, by way of example, with reference to the accompanying diagrammatic drawings, in which:

Figure 1 is a perspective and partly cross-sectional view of a microwave circuit substrate with a semiconductor device body which is to be mounted in a recess on the substrate;

Figure 2 is a cross-sectional view of the device body being pressed into the surface of the substrate

in a manufacturing method in accordance with the invention;

Figure 3 is a similar cross-sectional view of the device body mounted in the substrate at a later stage in the manufacture, and

Figure 4 is a similar cross-sectional view of the device body about to be pressed into the surface of a different microwave circuit substrate in another manufacturing method in accordance with the invention.

It should be noted that all of the Figures are diagrammatic and not drawn to scale. The relative dimensions and proportions of some parts of these Figures have been shown greatly exaggerated or reduced for the sake of convenience and clarity in the drawings.

In the particular example now to be described the device body is of a microwave Mott mixer diode substantially as described in the previously mentioned symposium paper by R. N. Bates et al and suitable for operation in millimetre wave systems in the frequency range 30 to 100 GHz. The device body comprises an electrically inactive support 1 of, for example, semi-insulating gallium arsenide material having a semiconductor active area 2 of, for example, epitaxially grown gallium arsenide at a part of the upper surface of the support 1. In the form illustrated in the accompanying drawings, the active area 2 is formed by etching away surrounding parts of the epitaxial layer to leave an upstanding mesa 2 on the semi-insulating support 1. However, the active area 2 may alternatively be isolated in the layer by proton bombardment of the surrounding parts of the layer so as to render these parts semi-insulating. The support 1 may be, for example about 0.1 mm. thick with a major surface area of about 0.2 mm. by 0.2 mm. The thickness of the active area 2 may be, for example, 3μm. (micrometres).

Electrode terminal areas 3 and 4 are present towards opposite ends of the upper surface of the support 1. The terminal area 3 is present directly on the inactive material, while the terminal area 4 illustrated in the drawings is present on a peripheral part of the mesa which provides the active area 2. If so desired, the terminal area 4 may extend directly on the inactive material of the support 1. Both the terminal areas 3 and 4 may be of, for example, gold.

The circuit substrate 10 illustrated in Figures 1 to 3 may be of the finline type and formed of, for example, a glass microfibre composition such as those available under the trade name RT/duroid from Rogers Corporation, Chandler, Arizona, U.S.A.. The dielectric substrate may be, for example, between 75 and 250 micrometres thick. The finline circuit is formed on the upper surface of the substrate 10 by a conductor pattern of which two separated parts 13 and 14 are illustrated in the drawings. The conductor pattern may be a layer of copper having a thickness of, for example, between 15 and 30 micrometres.

The diode body is to be mounted in the microwave circuit at the area 11 shown in dotted outline in Figure 1. In accordance with the present invention, a recess 15 having substantially the same shape and depth as the diode body 1,2 is formed at the area 11 by pressing the device body 1,2 into the surface of the substrate 10 to deform the substrate locally until the upper surface of the device body 1,2 is at substantially the same level as the conductor pattern 13,14 beside the recess 15. This stage is illustrated in Figure 2 which is a cross-section on the line II-II in Figure 1.

The substrate 10 is mounted on a work holder 20 which for this embodiment is apertured below where the recess 15 is to be formed. The diode body 1,2 is carried on a vacuum tool head 21 which engages the electrically inactive periphery of the support 1. The body 1,2 is pressed into the substrate 10 by the tool head 21 until the flat end surface of the tool head 21 is at a preset distance above the work holder 20 corresponding to the thickness of the substrate 10.

An advantage of the device body 1,2 having an electrically inactive support 1 is that the shape of the recess 15 formed in the substrate 10 is determined by the shape of the support 1 so that any probability of the active area 2 being damaged by the pressing operation is reduced. The recess 15 may be formed by a combination of pressure and heat. Thus, the device body 1,2 may be heated via the tool head 21.

In one particular example of this process the substrate 10 was of material available under the trade name RT/duroid-5880 having a thickness of 125 micrometres. The device support 1 was of semi-insulating gallium arsenide having a thickness of 100 micrometres and a major surface area of 200 micrometres by 200 micrometres. The device body 1,2 was heated to about 150°C by 200 micrometres. The device body 1,2 was heated to about 150°C and pressed into the substrate 10 with a load of 100 gms. The substrate holder 20 was at a temperature of about 25°C. Under these circumstances the formation of the recess 15 was found to deform the lower surface of the substrate outwards by about 10 micrometres directly below the recess 15, see Figure 2. This deformation of the lower surface was acceptable in the particular finline circuit being formed.

When the diode body 1,2 is pressed into the substrate 10 it is held in the substrate 10 by the walls of the resulting recess 15 which abut the sides of the diode body 1,2. The diode body is electrically connected into the circuit by depositing conductive layer portions 23 and 24 from the device terminal areas 3 and 4 to the conductor pattern portions 13 and 14, as illustrated in Figure 3. Because the device body 1,2 is such a good fit in the recess 15, these conductive layer portions 23 and 24 extend directly across the adjacent edges of the device body 1,2 and of the recess 15, are of short length so having a low inductance. Any possibility of these connections 23 and 24 short-circuiting the diode is reduced by the electrically inactive material of the support 1 over which these connections extend.

The layer portions 23 and 24 may be of an electrically conductive adhesive which is applied onto the areas where the connections are required. In a particular example a gold-loaded epoxy film having a thickness of about 20 to 30 micrometres has been used to form connections 23 and 24. The diode body 1,2 is secured to the substrate by the connec-

tions 23 and 24 and by the abutting walls of the recess 15 so that a mechanically strong mounting is obtained as well as a very low inductance. This secure mounting is particularly important for avoiding degradation of the D.C. and microwave performance if the circuit is subjected to vibrations or accelerations.

Figure 4 illustrates a modification in the method described for Figures 1 to 3. In the Figure 4 arrangement a recess 25 which is smaller than that required for the diode body 1,2 is first formed in the upper surface of the substrate 10. This smaller recess may be formed by, for example, pre-pressing a heated tool-head into the substrate. The depth of the recess 25 is slightly less than the thickness of the device support 1 and its transverse dimensions are also slightly less than those of the lower major surface of the device support 1. This smaller recess is subsequently enlarged to have substantially the same shape and depth as the device body 1,2 by pressing the device body 1,2 into this recess 25 by means of the tool 21. The subsequent manufacturing steps for providing connections 23 and 24 may be the same as those used for the arrangement of Figures 1 to 3. The arrangement of Figure 4 is particularly useful for less easily deformable substrate 10 or thicker substrate 10, for example substrates available under the trade name RT/duroid but having a thickness of about 250 micrometres or more. The arrangement of Figures 4 may also be used when it is desired to avoid or reduce deformation of the lower surface of the substrate 10, for example the circuit may be of the microstrip type having a conductive ground plane 18 on its lower surface.

Many other modifications are possible in accordance with the present invention. Thus, for example, although the previously-mentioned glass microfibre compositions have particularly low loss characteristics, the substrate 10 may be made of other deformable dielectric materials, for example materials available under the trade name mylar or under the trade name polyguide. Instead of forming the connections 23 and 24 by a conductive adhesive film, metal foils may be used, or the device body 1,2 may even have electrode terminals 3 and 4 in the form of beam leads which protrude beyond the sides of the body 1,2 and which are bonded directly to the substrate conductors 13 and 14 after the device body 1,2 is pressed into the substrate 10. Instead of mixer diodes other microwave semiconductor devices may be mounted in microwave circuits in this manner in accordance with the invention, for example field-effect transistor bodies.

CLAIMS

1. A method of manufacturing a microwave circuit in which a semiconductor device body is mounted in a recess on a dielectric substrate of the circuit and electrically connected to a conductor pattern at the upper surface of the substrate, characterized in that the recess is formed with substantially the same shape and depth as the device body by pressing the device body into the surface of the substrate to deform the substrate locally until the upper surface of the device body is at substantially the same level as the conductor pattern beside the recess, and in that the electrical connections are formed by conductive layer portions which extend directly across the adjacent edges of the device body and of the recess.

2. A method as claimed in Claim 1, further characterized in that, after pressing the body into the surface of the substrate, the conductive layer connections are formed by depositing areas of an electrically conductive adhesive across the edge of the recess.

3. A method as claimed in Claim 2, further characterized in that the electrically-conductive adhesive is a gold-loaded epoxy.

4. A method as claimed in anyone of the preceding Claims, further characterized in that the device body is heated so as to deform the substrate locally by thermocompression.

5. A method as claimed in anyone of the preceding Claims, further characterized in that the dielectric substrate is a glass microfibre composition.

6. A method as claimed in anyone of the preceding Claims, further characterized in that, before pressing the semiconductor device body into the surface of the substrate, a smaller recess is formed at the area of the upper surface where the device body is to be mounted, and in that this smaller recess is enlarged to have substantially the same shape and depth as the device body by pressing the device body into this smaller recess.

7. A method as claimed in anyone of the preceding Claims, further characterized in that the device body comprises a support of electrically inactive material having a semiconductor active area at a part of the upper surface of the support, in that electrode terminal areas of the device are present towards opposite ends of the upper surface of the support with at least one of the electrode terminal areas directly on the inactive material, and in that the shape of the recess formed in the substrate is determined by the shape of the support of electrically inactive material.

8. A method of manufacturing a microwave circuit substantially as described with reference to Figures 1 to 3 or Figure 4 of the accompanying drawings.

9. A microwave circuit manufactured by a method claimed in anyone of the preceding Claims.

New claims or amended claims filed on 28 March 1984
Superseded claims 1 and 7
New or amended claims:-
Original Claims 6, 8 and 9 renumbered as 8, 9 and 10 respectively.

1. A method of manufacturing a microwave circuit including a dielectric substrate and a semiconductor microwave device which has a device body mounted in a recess of the dielectric substrate and which is electrically connected to a conductor pattern at the upper surface of the substrate, the device body comprising a support of electrically

inactive material having at its upper side a semiconductor active area with an electrically inactive periphery, characterised in that the recess is formed with substantially the same shape and depth as the device body by pressing the device body into the surface of the substrate to deform the substrate locally until the upper surface of the device body is at substantially the same level as the conductor pattern beside the recess, the device body being pressed by a tool head so shaped as to engage the electrically inactive periphery without pressing against the active area, and in that the electrical connections are formed by conductive layer portions which extend directly across the adjacent edges of the device body and of the recess.

6. A method as claimed in anyone of the preceding Claims, further characterised in that the semiconductor active area is an upstanding mesa at a part of the upper surface of the support, and in that the upstanding mesa is accommodated within a recess in the tool head during the pressing operation such that the tool head engages the peripheral part of the upper surface of the support.

7. A method as claimed in Claim 6, further characterised in that electrode terminal areas of the dlevice are present towards opposite ends of the upper surface of the support with at least one of the electrode terminal areas directly on the inactive material of the support, and in that the shape of the tool head is such as to engage the electrically inactive periphery without pressing against the electrode terminal areas.

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